SkyPilot Link Budget Calculations – 4.9-5.8 GHz

Link budget defines the amount of power available in a communication link for transmission loss through the path, whether the loss is through the air or through obstructions like trees and buildings. With a known link budget, the range of a communication link can be determined given a fixed path loss and fade margin. Because of the large variation in path loss models for propagation in real world environments, the link budget becomes a more easily comparable specification for evaluation of communication systems. It is generally true that a higher link budget will provide longer range. For this reason, link budget is an important specification for all RF deployments.

The basic equation for link budget is a fairly simple formula when using units of power in dB.

Link Budget = Transmit Power + Transmit Antenna Gain + Receive Antenna Gain - Receiver Sensitivity

Transmit Power

"Transmit power" is the power coming out of the radio/power amplifier and into the antenna. Transmit power is normally measured in dBm. Although many companies highlight peak power, it is not accurate to use peak power for link budget calculations. Instead, link budget calculations should always use average power. If you've ever used a stereo with a power output display, you should be able to understand the difference between peak power and average power. A general rule of thumb is that the average power is about 5 to 7 dB less than the peak power. As an example, the FCC limits the maximum peak power in the UNII (5.725 to 5.850 GHz) frequency band to 1 W/30 dBm, which would translate to an average power for link budget calculations around 23-25 dBm.

SkyPilot's systems are FCC rated at a peak power of about 26.5 dBm and the average power output changes slightly depending on the modulation. For the lower modulations (BPSK & QPSK), the output can be driven harder so the average power is 22.0 dBm. For the higher modulations (QAM), the average power is 19.3 dB. This is generally referred to as amplifier back off.

Antenna Gain

"Antenna gain" represents the gain of the antenna relative to a single point antenna radiating evenly in all directions (sphere). So the gain is actually a measure of how well focused the antenna is at radiating the signal. The important thing about antennas is that the larger the antenna the larger the gain and the smaller the focus. Improvements in antenna are especially beneficial to link budgets because they are counted twice, once for the transmit antenna and once for the receive antenna. SkyPilot's infrastructure products (SkyGateways and SkyExtenders) have an array of eight antennas, each with 18 dBi of antenna gain and the CPE products (indoor and outdoor SkyConnectors) have an antenna with 17 dBi of antenna gain.

SkyPilot Antenna Characteristics

Product	SkyGateway/SkyExtender	SkyConnector
Antenna Gain	18 dBi	17 dBi
Elevation beam width	6.3°	9.2°
Azimuth beam width	45°	28°

Receiver Sensitivity

"Receiver sensitivity" is a measure of the minimum signal level that can be received by a radio. The word "received" has to be defined in terms of the quality of the link. For our system we use a 10% packet error rate (PER) as the metric for link quality (this is the same metric used by RF chip companies as well). Testing is done with no external interference and the signal power is reduced until a 10% PER occurs, at which time the average power is then measured. Receiver sensitivity changes with modulation and data rates as shown in the table below:

SkyPilot Measured Receiver Sensitivity

Data Rate	Modulation Format	Receiver Sensitivity
6 Mbps	BPSK – 1/2	-90.0 dBm
9 Mbps	BPSK – 3/4	-87.5 dBm
12 Mbps	QPSK – 1/2	-86.0 dBm
18 Mbps	QPSK – 3/4	-84.0 dBm
24 Mbps	16QAM – 1/2	-80.0 dBm
36 Mbps	16QAM – 3/4	-78.0 dBm
48 Mbps	64QAM – 1/2	-70.0 dBm
54 Mbps	64QAM – 3/4	-68.0 dBm

Link Budget Performance Summary

The summary for SkyPilot's link budget can therefore be calculated as follows:

Modulation Rate	Transmit Power	Transmit Antenna Gain	Receive Antenna Gain	Receiver Sensitivity	Link Budget
6 Mbps	22.0 dBm	18 dBi	18 dBi	-90.0 dBm	148.0 dBm
9 Mbps	22.0 dBm	18 dBi	18 dBi	-87.5 dBm	145.5 dBm
12 Mbps	22.0 dBm	18 dBi	18 dBi	-86.0 dBm	144.0 dBm
18 Mbps	22.0 dBm	18 dBi	18 dBi	-84.0 dBm	142.0 dBm
24 Mbps	19.3 dBm	18 dBi	18 dBi	-80.0 dBm	135.3 dBm
36 Mbps	19.3 dBm	18 dBi	18 dBi	-78.0 dBm	133.3 dBm
48 Mbps	19.3 dBm	18 dBi	18 dBi	-70.0 dBm	125.3 dBm
54 Mbps	19.3 dBm	18 dBi	18 dBi	-68.0 dBm	123.3 dBm

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